Attorney Docket No.: 021180-8.00US

# PATENT APPLICATION

# METHOD AND APPARATUS FOR AN ENVIRONMENTALLY HARDENED ETHERNET NETWORK SYSTEM


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## CROSS-REFERENCES TO RELATED APPLICATIONS

**[01]** NOT APPLICABLE

## STATEMENT AS TO RIGHTS TO INVENTIONS MADE UNDER FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

**[02]** NOT APPLICABLE

## REFERENCE TO A "SEQUENCE LISTING," A TABLE, OR A COMPUTER PROGRAM LISTING APPENDIX SUBMITTED ON A COMPACT DISK.

**[03]** NOT APPLICABLE

## BACKGROUND OF THE INVENTION

**[04]** The present invention relates to an environmentally hardened ETHERNET-type network, herein called a Neighborhood Area Network (NAN). More particularly the invention relates to apparatus and methods for power distribution while improving reliability and extending maximum usable distance between active elements in an environmentally harsh practical NAN.

**[05]** A NAN differs from a Local Area Network (LAN) in several ways: 1) a NAN deploys environmentally hardened cable and connector technology in addition to aerial and underground buried enclosures, techniques and technology; 2) a NAN provides a self-sufficient power distribution system integrated with an environmentally hardened data distribution system to power environmentally hardened repeaters, hubs and switches; and 3) network active elements are employed which are configured to increase the average distance between the active elements.

**[06]** DESCRIPTION OF THE RELATED ART

**[07]** Several types of LANs have been developed, including ATM, Frame Relay, Token Ring, and particularly Ethernet as set forth by the IEEE 802.3 standard. Under this standard, in section 802.3u, 100Base-TX (100 Mbit) baseband data signals are transferred over insulated copper wires called unshielded twisted pairs (UTP) such as CAT-5,

with one set of pairs used for communication down the line toward network devices (the down link) and a second twisted pair is used for communication up the line (to the server, the up link). However, the designated transmission distances are limited to the IEEE 802.3 specified 100 meter maximum that is based upon CSMA/CD collision domain and CAT-5 attenuation criteria. Hence, when significantly longer distances are required (and economics justify it), the more expensive 100Base-FX fiber optic technique has been employed. Compared to CAT-5, fiber cable has much higher capital and outdoor installation costs to terminate and to protect the delicate fibers. Fiber transceiver nodes are also much more expensive than for copper based twisted pair. Consequently, economics have encouraged the widespread proliferation of 100Base-TX CAT-5 based LAN systems, with fiber used only for longer trunk lines between work groups. Fiber cable is a dielectric and cannot conduct electrical power. (In this document the term CAT-5 is used to represent the broad variety of UTP network cable, including CAT-5e, CAT-6 and shielded pair cable.) Recent developments in 1000BaseT technology include the copper based 802.3ab specification and 802.3z fiber specification, which are competing with several other Gigabit and "10Gig" technologies, that in time may or may not prove their value in the marketplace. It is anticipated that the electrical specifications will benefit from the environmental hardening addressed by the present invention.

**[08]** LANs are deployed within premises (for networking work stations and their peripherals) and usually have access to the environmental protection and AC power system of the premises. CAT-5 with RJ-45 connectors is the cabling configuration conventionally deployed for interconnecting network equipment (such as a hub, switch or network interface card or NIC). The RJ-45 is an 8 position, 8 contact plastic connector related to the RJ-11 (6 position, 2 or 4 conductor) telephone wire type of connector. Most RJ-45 connectors are inexpensive and readily connected to the 4 pairs of a CAT-5 with a commercial crimping tool. Most network devices have RJ-45 jacks for receiving CAT-5/RJ-45 plugs.

**[09]** However, RJ-45 connectors have reliability limitations related to the mechanical design of the contacts. Outdoor deployment of RJ-45 connections has resulted in reliability concerns. The jack portion of the connector consists merely of wires that are slightly springy and held in position by grooves in the body of the connector. The plug portion of the RJ-45 connector consists of thin conductor elements sandwiched between plastic insulation that is the body of the RJ-45 plug. Contact is made between the wires in the jack and the conductors in the plug over approximately 0.06in length of the plug conductors.

The contact is a low reliability single-surface contact because the contact area is so small and because the RJ-45 plug is held in the jack by a plastic arm that is not positive enough to hold the plug securely in the jack when torque or stress is applied to the CAT-5 wire mechanically crimped to the jack. Consequently, particularly in harsh outdoor installations and even in indoor environments, the RJ-45 jack demonstrates reliability problems. The mechanical problems are increased in the outdoor environment not only due to the temperature extremes, high humidity and dirt levels but also because the outdoor gel filled CAT-5 that is deployed in outdoor environments is so stiff that it multiplies the torque applied to the plug and increases the unreliability of the single-surface connections.

**[10]** LANs usually employ the standard premises AC power system to supply power to the network components. Often a wall transformer/power supply is plugged into an AC outlet and connected via barrel connector to each hub or switch. Larger switches may contain their own power supply. But when the installation of certain components must be made in locations that are not conveniently proximate to AC power sources, power must be supplied either by installing retrofit AC power circuits, by using batteries or by employing the CAT-5 wiring itself.

**[11]** Conventional CAT-5 cable contains 4 twisted pairs: one pair for uplink signals; a second pair for down link signals, while the third and/or fourth pairs, not normally used for signals, may be used for limited power distribution. The amount of power that can be transferred via CAT-5 cable is limited by the resistance of 24 gauge CAT-5 wire (9-10 ohms per 100m) as well as the dielectric and electrical code limitations on voltage range (23060V, depending on jurisdiction). On a practical basis, the total equivalent resistance for the power circuit comprises the sum of the source and return wire resistances. For example, a 6 Watt switch operating at 3.3 V consumes nearly 2A, which in turn dictates that a 100 meter length of CAT-5 would drop nearly 34 V and 60 Watts in the wire alone (clearly impractical). US 5,994,998 describes an alternate technique for using the signal pairs in a CAT-5 cable to carry power, thereby reducing the resistance by a factor of 2. However, the technique described in this patent remains impractical (for longer distances, at least). The US 5,994,998 technique is further limited by the following factors: 1) the degradation of the signal to noise ratios caused by increased noise generated by power supply current through greater lengths of cable on top the decreased signal level; and 2) the high cost of quality inductors required to isolate signals from power without seriously altering the delicate IEEE 802.3u spec for 100Base-TX signals. Further, if the other 2 pairs are used for a second set of signals to a

separate network device, then crosstalk noise becomes a serious issue over longer lengths of CAT-5 approaching the 100m limit.

**[12]** What is needed is a cabling scheme and method of deployment, which address and overcome the practical limitations to the use of CAT-5 type wiring in an environmentally harsh environment.

## SUMMARY OF THE INVENTION

**[13]** According to the invention, in an environmentally hardened network, a data and power distribution cable is employed in connection with reliable end connectors, high performance physical layer transceivers clocked at a lower rate than is specified and full duplex switched packet transmission techniques between switched nodes in order to extend operational distance between network elements. In a specific embodiment, the data and power distribution cable comprises a data distribution element, a power distribution element, an optional strain distribution element, an optional hollow conduit, and an extra shield and outdoor sheath. The cable may incorporate: 1) a Gel filled outdoor UTP (CAT-5) cable; 2) end connectors of type DB-9 [D-Sub] for connection of the UTP to network equipment; 3) power transmission cable of wire gauge sufficient to carry the power required by network equipment (switches, etc) for the specific segment of the network; and optionally 4) a hollow conduit that permits installation of optical fiber before or after installation of the cable.

**[14]** For reliability in the outdoor environment, the NAN requires the use of a mechanically and electrically reliable connector. An example of a preferred embodiment is a DB-9 plug and jack for the cable and the network equipment. The preferred connectors are configured to maintain adequate physical and electrical contact over a range of operationally harsh environmental conditions. The connectors preferably have gold plated pins and sockets and make contact with each other over the entire circumference and length of the pins; the plugs and receptacles of the special connectors interlock with protective housings or shells that shield the contact area from dirt, moisture and EMI and that contain within the contact area protective contact dielectric gel; and the plugs and receptacles have secured mechanical clasping mechanisms such as screws and threads that clamp the connectors together, providing strain relief from cable torque or stress. The entire construction provides much more mechanical robustness and environmental integrity for either indoor or outdoor network data connections.

**[15]** According to a specific embodiment of the invention, high performance physical layer transceivers (herein high PHYs) are employed at lower than

specified clock rates in the network equipment to extend range and increase reliability. According to a further specific embodiment of the invention, full duplex switched packet transmission techniques are used between switched nodes thereby avoiding distance limiting CSMA/CD protocols.

**[16]** To increase the data rate of the NAN backbone with minimal cost, several copper (or fiber) ports can be "trunked" over a single CAT-5 by using all 4 pairs, 2 for each of the 2 ports. In trunking, UTP pairs support simultaneous transmission in a common direction in a manner that share data traffic between them. This technique can provide a data rate increase from 100Mbps to 200Mbps full duplex (400Mbps total) with very little increase in cost. The DB-9 connector can be structured to provide both ports at a single connector to facilitate the trunking option, or the power lines can be branched within a secure enclosure to a high current power connector and power distribution network, from which power is shunted to local equipment.

**[17]** The invention will be understood with reference to the following detailed description in connection with the accompanying drawings.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[18]** Figure 1 is a block diagram of a power and data distribution system in an environmentally hardened network according to the invention.

**[19]** Figure 2 is a block diagram of a typical data and power distribution node.

**[20]** Figure 3 is a schematic diagram of a cable connection and power manager according to the invention.

**[21]** Figure 4 is a cross-sectional view of an environmentally hardened cable for data and power distribution according to the invention.

**[22]** Figure 5 is a block diagram of a switch containing a high performance physical layer transceiver for each port.

## DETAILED DESCRIPTION OF THE INVENTION

**[23]** Figure 1 is a diagram of an environmentally hardened network, herein a NAN system 100, that integrates both data and power distribution function. A NAN Distribution box 101 contains a switch or, if enhanced, a router for connecting to a larger environmentally hardened ETHERNET network. It is assumed that there is a network operation center (NOC) (not shown) providing various network services via ETHERNET

protocols. The distribution may be via fiber cabling 104, for example. The NAN fiber uplink cable 104 could also be part of a routed fiber loop running gigabit Ethernet or other high-speed fiber protocols. Distribution box 101 may be powered by AC power drop 102 that sources metered AC power (115/230VAC in the US) from a utility company service line or generator. Distribution box 101 supplies power and data through a cable 103 according to the invention to at least one distribution segment of the NAN, as illustrated. NAN cable 103 carries data and power to the uplink port of a switch 1 105 (such as an aerial enclosure or a buried enclosure) that in turn downlinks both power and data to the uplink port of a switch 2 111 as for example across a street or other right-of-way. Switch 1 105 also downlinks data through conventional outdoor CAT-5 to premises/homes 107 and 108. Switch 2 111 downlinks data through outdoor CAT-5 UTP cabling 110, 112 and 115 to premises 109, 103 and 116. Premises 109 illustrates a conventional personal computer (PC) connection via direct connection to a conventional network interface card (NIC) to CAT-5 110. CAT-5 110 is operably installed from the aerial wiring into premises 109 to the room in which the PC is located. This represents a variety of premises network devices served by the NAN. Any of the premises represented diagramatically by the "house" symbol can be any type of residential, commercial or industrial structure or enclosure containing network devices. Aerial switch 111 also downlinks data and power via NAN cable 117 to the uplink port of aerial switch 3 118.

**[24]** Figure 1 also illustrates the underground or buried type of NAN installation. Switch 2 111 also downlinks data and power through buried environmentally hardened NAN cable 114 according to the invention and under a street to the uplink port of a first pedestal (Ped 1) 123 providing underground wiring services to customers. Ped 1 123 in turn provides downlinks of data to customers 125 through 128 through buried outdoor CAT-5 124, etc. In addition Ped 123 provides downlinks of data and power to Peds 130 and 136 via underground cable 129 and 135, respectively, that in turn provide downlinks of data to premises 132 through 134 and 138 through 140.

**[25]** Any practical number of downlink aerial or pedestal mount switches is permitted. The suitable number of switched nodes and ultimate length or distance of the segments is determined by power supply capacity, power distribution current capacity as determined by wire gauge (wire size), switch power consumption, average network loading per customer, the number of customers per distribution segment and data latency for specific applications. Power supply boxes can be installed where needed to supply system power to remote locations of a NAN distribution segment, with AC power supplied by extra

distribution wires in the cable or by additional power drops, where available. Any switch can downlink to as many nodes or additional switches as it has ports available.

[26] Figure 2 is a diagram of a NAN distribution box 101 illustrating its typical internal components with their connections to other components of a NAN distribution system 100. Fiber or other media uplink cable 104 is operably connected to a switch or router element 204 through its uplink port UL. Cables 103 and optionally 206 according to the invention each distribute data and power to distribution elements, such as switch 1 105 (Figure 1). Data from switch 204 through downlink port 1 DL1 is connected via environmentally-hardened DB-9 connector to CAT-5 cable 203 of distribution cable 103. Similarly, data from downlink port 2 DL2 is connected via DB-9 connectors to the CAT-5 cable 205 of distribution cable 206. Power through cable 212 is distributed via bus 201 to the power section 213 of distribution cable 103 and, similarly, power via extensions of cable 212 is distributed via bus 202 to the power portion 216 of distribution cable 206. Any practical number of distribution segments can be served by a distribution box 101. A typical network device served by the distribution box is a network switch.

[27] It is economically prohibitive to employ 50 Ampere power drops from utility power lines where only two to ten watts of network device power is required. The power for at least one network segment can be supplied from AC power drop 102 by power conditioner 207 that filters out transients and EMI, limits current for fault conditions and supplies conditioned AC to power supply 209. Optionally a transformer may provide robust (4KV) isolation from common mode power supply transients. Storage battery 210 provides DC power to power supply 209 in the event that AC power 102 is interrupted for any reason. Together with power control 211, an uninterruptible power supply (UPS) services the power requirements of network equipment on associated segments. Storage battery 210 may be sized to permit the backup time required by a particular environment and applications.

[28] The power distribution system is integrated with the data transmission system by means of shielded 10 gauge to 16 gauge wire or by use of coaxial cable of sufficient gauge in the center conductor to support currents as high as 60 Amperes, but typically on the order of 15 Amperes. Integration of the power distribution system into the NAN is necessary because it is unacceptable technically and logistically to power network switches and hubs from a customer's premises power and because it is economically prohibitive

[29] Power control 211 permits remote control and diagnostics of the power supply for distribution segments and switch/router 204 for increased reliability. Power

control 211 typically contains a network port with a communications controller (not shown) for connection via CAT-5 214 to network administration resources provided by switch/router 204.

[30] Figure 3 provides a schematic of NAN cable 103 (106,114,117,129 or135) according to the invention suitable for NAN requirements. Figure 4 is a cross-section of such a cable. The overall cable 103 is covered with a heavy weather resistant outer sheath 415 outside a foil shield and drain wire 414, which provide EMI and electrostatic discharge protection. This permits the cable to be sown underground with a vibratory plow, pulled through buried conduit or lashed to aerial wiring systems. A removable strain cable 417 siamesed to the outer sheath by a sheath extension 415A provides for suspension and strain relief. A UTP cable 203 comprises at least four twisted pairs 401 through 408 (CAT-5 standard) and incorporates low loss electrical design to extend signal transmission range. A UTP insulating sheath 409 is also provided which increases environmental and mechanical robustness. DB-9 connector 301 and power connector 302 permit increased reliability and connection to network devices. The first port employs two twisted pairs that are color-coded. For example, a blue pair (wires 401 and 402) and a brown pair (wires 403-and 404) are connected to corresponding pins 1, 6, 2 and 7 of connector 301. An optional second port employs a green pair (wires 405 and 406) and an orange pair (wires 407 and 408) that are connected to corresponding pins 4, 8, 5 and 9 of connector 301. Each pair of wires supports transmission in one direction such that two pairs support a full duplex network connection. Providing four pairs permits the internal logic of a switch (204) to be configured by network managers to "trunk" the data of two ports together to double the data rate of a NAN connection. Alternately, two independent network connections may be made through one connector (and one cable) or through two separate connectors and two separate cables.

[31] Referring again to Figure 3, power cable 213 permits transmission of power between remote NAN power supplies and NAN devices. Power shield 412 (incorporating a ground return wire) reduces EMI from entering or leaving the power distribution wires as well as providing a competent return path for accidental shorts. Insulated power wires 410 and 411 are sized according to NAN segment load requirements and power distribution voltages of to permit adequate transmission of NAN power. Insulation sheath 413 insulates and environmentally protects power wires and shield.

[32] Power cable 213 is connected to power bus 201 via connector 302. Power bus 201 contains power filtering and transient protection devices as well as bus connectors 303 and 304 for distributing power to other network segments. Bus 201 also

connects NAN cable shields to ground by means of ground pins on all power cable connectors and by means of ground connectors 306 and 307. Common mode transient and EMI filtering is provided by Transient Voltage Protector (TVS) 308 and capacitor 310, while differential over voltage, transient and EMI filtering is provides by TVS 312 and capacitor 309. Resettable fuse (or positive temperature coefficient thermistor) 305 also provides over current/short circuit protection for selected branches of the NAN power distribution system.

[33] Use of a properly sized ground return wire permits employment of higher distribution voltages in the power wires, in compliance with electric and safety codes. Employment of a higher distribution voltage provides for lower distribution current with attendant lower copper power losses. (P=VI). Thus, by using higher voltage (60V or higher) switching regulators in network devices, a 60 VDC or ACpeak (100 W) distribution voltage can provide power for over thirty 8-port switches in a copper NAN segment distributed over 10,000 feet of NAN cable and economically networking over 120 houses in a neighborhood. The capability of providing 5000-10,000 foot long copper NAN distribution segments also permits convenient and economical installation of distribution boxes at central locations for connection to AC line power taps as well as fiber or copper uplinks to the NAN servers.

[34] Referring to Figure 4, to facilitate pulling of fiber cable through tube 416, a messenger wire 418, such as a stainless steel wire, may be installed during the manufacturing process. Alternate commercial techniques are available for installing fiber into the fiber buffer tube 416 during or after the manufacturing or installation process. Individual shielding of wires or pairs of wires can accommodate special transmission criteria for special copper physical layer data transmission technologies.

[35] Figure 5 is a block diagram of a switch 204 with high performance physical layer transceivers (PHY) 502, 503 (representing 2 of 2N ports) and a switch chip 501. A suitable switch chip is a type AL125 chip from Broadcom of Irvine, CA. Intel Corporation of Santa Clara, CA also manufactures a suitable switch chip such as a Model IXE2412 or IXE2424 device. A suitable PHY 502 or 503 is of the Alaska™ family of 1000BaseT transceivers, such as a type 88E/1000 Gigabit Ethernet transceiver from Marvell Company of Sunnyvale, CA. A choice of a single clock input or multiple clock inputs is accommodated. The receive and transmit clocks 504 for the PHY 502 are typically set at less than the design clock speed of the PHY in order to promote greater distance between nodes. Under clocking down to one tenth of the 125MHz design clock rate can extend PHY transmission range to over 500m at 100 Mbps. The PHY at the uplink port of the next switch (switch 105 for example) requires matching under clocking rates to achieve best performance

with PHY 502. Switch clock 505 for the switch chip 501 may be totally independent of clock 504 or 506. Clock 506 may be set for PHY 503 to operate with a fiber port 104 or with another UTP port operating at Gigabit speeds. The typical PHY 502 performs A to D conversion on received signals from connector 301 via isolation module 508, performs detection and some intelligent filtering and packaging of packets, then provides digital signals to the switch chip 501, which then redirects and forwards the reconstructed digital signals to a destination PHY 503, which in turn performs D to A conversion for the transmitted analog signal at the destination port 507 for transmission over link 104.

**[36]** The invention has been explained with reference to specific embodiments. Other embodiments will be evident to those of ordinary skill in the art. It is therefore not intended that this invention be limited except as indicated by the appended claims.